California Air Resources Board

Revised Quantification Methodology for Agricultural Lands Conservation

September 6, 2019

TABLE OF CONTENTS

TABLE OF TABLES

TABLE OF FIGURES

TABLE OF EQUATIONS

Section A. Introduction

California Climate Investments is a statewide initiative that puts billions of Cap-and-Trade dollars to work facilitating greenhouse gas (GHG) emission reductions; strengthening the economy; improving public health and the environment; and providing benefits to residents of disadvantaged communities, low-income communities, and low-income households, collectively referred to as “priority populations.” Where applicable and to the extent feasible, California Climate Investments must maximize economic, environmental, and public health co-benefits to the State.

The California Air Resources Board (CARB) is responsible for providing guidance on estimating the GHG emission reductions and co-benefits from projects receiving monies from the Greenhouse Gas Reduction Fund (GGRF). This guidance includes quantification methodologies, co-benefit assessment methodologies, and benefits calculator tools. CARB develops these methodologies and tools based on the project components eligible for funding by each administering agency, as reflected in the program expenditure records available at: www.arb.ca.gov/cci-expenditurerecords.

CARB staff developed this Quantification Methodology (QM) to estimate the avoided GHG emissions and air pollutant emission co-benefits associated with agricultural lands conservation. The QM includes equations to estimate benefits of each proposed project component. This methodology uses calculations to estimate avoided emissions from reduced vehicle miles traveled (VMT), reduced utility use, and avoided loss of soil organic carbon. Programs this Quantification Methodology may be used for include, but are not limited to:

- Sustainable Agricultural Lands Conservation Program (SALC), administered by the Strategic Growth Council (SGC) and the Department of Conservation (DOC)
- Climate Adaptation Readiness Program (CARP), administered by the Wildlife Conservation Board (WCB)

The Agricultural Lands Conservation Benefits Calculator Tool (Tool) automates methods described in this document and outlines documentation requirements. Projects will report the total project GHG emission reductions and co-benefits estimated using the Agricultural Lands Conservation Benefits Calculator Tool as well as the total project GHG emission reductions per dollar of GGRF funds requested. The Agricultural Lands Conservation Benefits Calculator Tool is available for download at: http://www.arb.ca.gov/cci-resources.

Using many of the same inputs required to estimate GHG emission reductions, the Agricultural Lands Conservation Benefits Calculator Tool estimates the following co-benefits and key variables from projects: Particulate Matter 2.5 microns or less (PM2.5) Reductions (in pounds), Diesel Particulate Matter (Diesel PM) Reductions (in pounds), Nitrogen Oxides (NO_x) Reductions (in pounds), Reactive Organic Gases (ROG) Reductions (in pounds), Passenger VMT Reductions (in miles), Fossil Fuel Based Transportation Fuel Use Reductions (gallons), Land Conserved (in acres), Soil Benefit (in acres) and Travel Cost Savings (in dollars). Key variables are project characteristics that contribute to a project’s GHG emission reductions and signal an additional benefit. Additional co-benefits for which CARB assessment methodologies were not incorporated into the Agricultural Lands Conservation Benefits Calculator Tool may also be applicable to the project. Applicants should consult agency guidelines, solicitation materials, and agreements to ensure they are meeting agency requirements. All CARB co-benefit assessment methodologies are available at: www.arb.ca.gov/cci-cobenefits.

This methodology uses calculations to estimate avoided GHG emissions and co-benefits associated with the implementation of a project due to:

- reductions in future vehicle miles traveled (VMT);
- changes in future electrical and heating use; and
- avoidance of agricultural soil carbon loss.

Projects will report the total project GHG benefit estimated using this methodology as well as the total project GHG benefit per dollar of GGRF funds requested.

Methodology Development

CARB developed this Quantification Methodology consistent with the guiding principles of California Climate Investments, including ensuring transparency and accountability.[1] CARB developed this Quantification Methodology to be used to estimate the outcomes of proposed projects, inform project selection, and track results of funded projects. The implementing principles ensure that the methodology would:

- Apply at the project-level;
- Provide uniform methods to be applied statewide, and be accessible by all applicants;
- Use existing and proven tools and methods;
- Use project-level data, where available and appropriate; and
- Result in GHG emission reduction estimates that are conservative and supported by empirical literature.

CARB reviewed peer-reviewed literature and tools and consulted with experts, as needed, to determine methods appropriate for the project activities. CARB also consulted with agencies responsible for agricultural lands conservation program implementation to determine project-level inputs available. The methods were developed to provide estimates that are as accurate as possible with data readily available at the project level. CARB released the Draft QM and Draft Tool for public comment in July 2019. This Final QM and accompanying Tool have been updated to address public commends, where appropriate.

In addition, the University of California, Berkeley, in collaboration with CARB, developed assessment methodologies for a variety of co-benefits such as providing cost savings, lessening the impacts and effects of climate change, and strengthening community engagement. Co-benefit assessment methodologies are posted at: www.arb.ca.gov/cci-cobenefits.

[1] California Air Resources Board. www.arb.ca.gov/cci-fundingguidelines

Tools

This Quantification Methodology relies on project-specific outputs from the following tools:

The Topologically Integrated Geographic Encoding and Referencing database (TIGERweb) and American Fact Finder are used to determine if the agricultural lands conserved are in rural or urban-designated areas. These tools provide a platform to access various data maintained by the Census Bureau, and are referenced in this Quantification Methodology to assist in determining the land use setting for a project. TIGERweb is available at: https://tigerweb.geo.census.gov/. American Fact Finder is available at: https://factfinder.census.gov/.

SoilWeb is used to determine the dominant soil order at the project site. SoilWeb was developed by the California Soil Resource Lab at University of California, Davis (UCD) and University of California Agriculture and Natural Resources (UCANR) in collaboration with the US Department of Agriculture Natural Resources Conservation Service (NRCS). SoilWeb explores soil survey areas using an interactive Google map and view detailed information about soils on the project site. SoilWeb runs in any web browser and is compatible with desktop computers, tablets, and smartphones. SoilWeb is available at: https://casoilresource.lawr.ucdavis.edu/gmap/.

In addition to the tools above, this Quantification Methodology relies on CARB-developed emission factors. CARB has established a single repository for emission factors used in CARB benefits calculator tools, referred to as the California Climate Investments Quantification Methodology Emission Factor Database (Database), available at: http://www.arb.ca.gov/cci-resources. The Database Documentation explains how emission factors used in CARB benefits calculator tools are developed and updated.

Agency staff will apply this Quantification Methodology and use the Agricultural Lands Conservation Benefits Calculator Tool to estimate the net GHG benefit and co-benefits of proposed projects.

Updates

CARB staff periodically review each quantification methodology to evaluate its effectiveness and update methodologies to make them more robust, user-friendly, and appropriate to the projects being quantified. CARB revised the Sustainable Agricultural Lands Conservation Program Quantification Methodology to this Agricultural Lands Conservation Quantification Methodology[2] to correct assumptions in the methodology, align database use with other quantitative methodologies for California Climate Investments programs, and to include additional project characteristics to estimate GHG reductions and co-benefits. The changes include:

- Assumption that the development rights extinguished by agricultural lands conservation results in the development of new housing in urban areas in place of the agricultural land, rather than extinguishment of new housing altogether;
- Revision of method to determine the residential zoning density to be applied to project sites;
- Adoption of the Department of Transportation's California State Travel Demand Model (CSTDM) to calculate residential trip length distances when verified VMT estimates from local agencies have not yet been submitted;
- Addition of changes in electricity demand and heating fuel types to the methodology;
- Addition of avoided agricultural soil carbon loss to the methodology; and
- Addition of new co-benefits using many of the same inputs used to estimate the net GHG benefits.

Due to the significant changes in the methodology, the Revised Quantification Methodology will be used to re-evaluate all previous agricultural lands conservation projects funded by the Greenhouse Gas Reduction Fund.

[2] Quantification Methodology for the Strategic Growth Council Sustainable Agricultural Lands Conservation Program, Fiscal Year 2016-17 & 2017-18. California Air Resources Board, April 18, 2018. https://ww3.arb.ca.gov/cc/capandtrade/auctionproceeds/final_sgc_salc_qm_16-18.pdf.

Section B. Methods

The following section provides details on the methods supporting emission reductions in the Agricultural Lands Conservation Quantification Methodology and Benefits Calculator Tool.

Agricultural Lands Conservation Project Types

Agricultural Lands Conservation programs protect critical agricultural lands at risk of conversion to urban and rural residential development, avoid GHG emissions from more GHG-intensive land uses, and provide additional co-benefits. There are two Agricultural Lands Conservation Project Types:

- Agricultural Conservation Easements
- Agricultural Lands Conservation Planning

Investments in agricultural conservation easements (easements) permanently protect strategically located, highly productive, and critically threatened agricultural land. Funding agricultural lands conservation planning projects results in the implementation of local and regional planning policies that protect agricultural lands from development through the establishment of growth boundaries, zoning ordinances, and/or the use of easements.

Easement-type projects directly result in the extinguishment of development rights, thereby avoiding increases in GHG emissions by limiting opportunities for expansive, vehicle-dependent and GHG-intensive forms of development. Planning projects enable future implementation of projects that can create benefits do not have an associated quantification methodology.

General Approach

The methodology used to estimate net GHG benefits and created co-benefits by protecting agricultural lands at risk of conversion is described in this section. In general, benefits are estimated as the difference between the baseline scenario (conversion of agricultural lands to households) and the project scenario (development of urban lands to the same number of households).

These methods account for reduced future VMT, reduced future electricity and heating demand, and avoided loss of agricultural soil carbon. The net GHG benefit is estimated using the approaches in Table 1.

Table 1. General Approach to GHG Quantification by Project Component

GHG emissions avoided from reduced future Vehicle Miles Traveled (VMT)
Net GHG Benefit = (GHG emissions associated with VMT) x (estimated VMT avoided from extinguishment of future housing developments at agricultural project site – estimated VMT created from future housing developments at urban sites)
GHG emissions avoided from reduced future electricity and heating demand
Net GHG Benefit = (GHG emissions associated with electricity use) x (estimated rural household electrical use – estimated urban household electrical use) + (propane heating (rural use) GHG emission factor - natural gas heating (urban use) GHG emission factor) x (estimated urban natural gas use)
GHG emissions avoided from avoided agricultural soil carbon loss
Net GHG Benefit = Soil Carbon Loss Rate due to Land Use Conversion x Soil Carbon Stock of graded areas of project site

Agencies will follow the steps outlined in Figure 1 to estimate the net GHG benefit from a proposed project. Detailed instructions for each step are provided on subsequent pages.

Figure 1. Steps to Estimating GHG Emission Reductions

Step 1. Define the Project

Step 2. Determine the Agricultural Land Conservation Inputs Needed

Step 3. Estimate the Number of Development Rights affected by Easement

Step 4. Determine the Urban or Rural designation for the Project Site using TIGERweb and American Fact Finder

Step 5. Determine the soil type of the Project Site using SoilWeb.

Step 6. Estimate the net GHG benefit and selected co-benefits for the Proposed Project

Step 1: Define the Project

For GHG quantification purposes, eligible agricultural lands conservation projects consist of two potential project activities. Applicants must identify the project activities from Table 2 that apply to the project. The project activities identified will determine which subsections of this Quantification Methodology are used in order to estimate the net GHG benefit.

Table 2. Project Activities and Appropriate Quantification Methods

Project Activity	Method Subsection References
Agricultural Conservation Easements	Steps 2 - 5
Agricultural Lands Conservation Planning Grants	No GHG Quantification

Step 2: Determine the Agricultural Lands Conservation Inputs Needed

Table 3 identifies the required data inputs needed to estimate the net GHG benefit and selected co-benefits for the proposed project by project component.

Table 3. Required Agricultural Lands Conservation Inputs for Eligible Project Components

ALL PROJECTS

General Information
1. Project Name
2. Contact Name, Phone Number and Email
3. Project site location
4. Project site area
5. Characteristics of project site and five miles around project site, including
  ○ Geography
  ○ Existing Infrastructure
  ○ Water bodies and Floodways
  ○ Current Zoning Designations
  ○ Elevations
6. Total amount of GGRF funds requested from relevant GGRF programs to implement the project, including GGRF funds previously awarded to the project and GGRF funds the project plans to request in the future; and
7. Identify California Climate Investments program(s) from which the project has been awarded GGRF funds (include award date), is currently requesting GGRF funds, or plans to request GGRF funds. For a list of GGRF funded programs, go to: ww2.arb.ca.gov/cci-funded-programs.

Step 3: Estimate the Number of Development Rights Affected by Easement

To quantify the avoided GHG emissions, determine the number of development rights to be extinguished. This is done by establishing the appropriate project geographic boundary, determining the appropriate zoning density, and then calculating the number of development rights to be extinguished.

Agencies will use the maps provided by applicants, in conjunction with any other relevant maps or resources available to agency staff, and Table 3 to establish project geographic boundaries for assessing agricultural lands

Current zoning may not accurately reflect the density level of development projects that could be expected for a given property, particularly if in close proximity to existing urban centers. The SGC/DOC SALC Guidelines defines the appropriate zoning density type for quantification purposes.[3]

Different sub-sections of the project area may be determined to be at risk under different risk criteria. If different portions of the project area are at risk of conversion to different zoning types, then the number of development rights to be extinguished must be separately determined for each sub-section with a different zoning density. If a portion of the project area is not determined to be at risk of conversion under any of the risk criteria, then no development rights are considered extinguished for these acres, and they are excluded from the GHG reduction calculations.

Areas within the project geographic boundary that contain features that present significant barriers to residential or rural residential development are not considered to be at-risk for the purposes of GHG quantification. Examples of such features include:

- FEMA floodways, rivers, and other waterbodies
- Land already protected for conservation

Acreages within these identified areas are not included in the total acres at risk, unless a land use plan or zoning code specifically states the land is considered developable.

Density Calculation for Risk of Conversion to Residential Areas

For the portion of the agricultural lands within the project geographic boundary determined to be at risk of conversion to residential zoning, determine the number of development rights to be extinguished based on residential zoning density. Zoning density will be calculated as such:

1. If the project site has a zoning proposal or land use plan with the number of dwelling units or density stated in the proposal or plan, that number or density shall be used to determine the number of development rights to be extinguished.

[3] Agricultural lands determined to be at risk of conversion to residential or rural-residential development using these risk criteria options will calculate the number of development rights extinguished according to the land-use density associated with the demonstrated risk, even if this differs from current zoning. When the risk-based density is higher than the current zoning density, it is referred to as "upzoning."

2. If there is no number of dwelling units or density stated in a zoning proposal or land use plan, the housing density within two miles of existing residential areas will be set to the average housing density of the newest residential zone within two miles of the project site. If the project site has grades exceeding 15%, the housing density for those areas will be reduced:
   - by 10 percent for areas with grades between 15% and 20%;
   - by 20 percent for areas with grades between 20% and 25%;
   - by 30 percent for areas with grades between 25% and 30%; and
   - to 0.5 dwelling units per acre for areas with grades greater than 30%.
3. A housing density of 0.5 dwelling units per acre will be used in all other cases.

Density Calculation for Risk of Conversion to Rural Residential Areas

For the portion of the agricultural lands within the project geographic boundary determined to be at risk of conversion to rural residential zoning, determine the number of development rights to be extinguished based on rural residential zoning density, calculated as follows:

1. If the project site has a zoning proposal or land use plan with the number of dwelling units or density stated in the proposal or plan, that number or density shall be used to determine the number of development rights to be extinguished.
2. If there is no number of dwelling units or density stated in a zoning proposal or land use plan, the housing density within five miles of existing rural residential areas will be set to the average housing density of the newest rural residential zone within five miles of the project site. If there are no rural residential zones within five miles but there is a residential zone within five miles, a housing density of 1 dwelling unit per 3 acres will be used. For areas at risk of conversion to rural residential zoning with grades greater than 30%, a housing density of 0.1 dwelling units per acre will be used.
3. A housing density of 0.1 dwelling units per acre will be used in all other cases.

Density Calculation for Risk of Conversion to Current Lot Minimums

For the portion of agricultural lands within the project geographic boundary determined to be at risk of conversion to current lot minimums, determine the number of development rights to be extinguished based on the property’s current agricultural zoning density.

Calculation for Number of Development Rights

The number of development rights to be extinguished is equal to the product of the zoning densities and the acreages of agricultural land within the project geographic boundary at risk of conversion to development, less any current or reserved houses pre-existing on the project site. Fractions of dwelling units will be rounded down for each calculation.

While some agricultural lands may be at risk of conversion to commercial, industrial, or recreational development, all projects will assume that one development right is equivalent to a single family dwelling unit when using this QM to estimate the avoided VMT and resulting avoided GHG emissions from a proposed project.

Agencies will provide a map identifying at-risk agricultural lands within the project geographic boundaries and the associated number of development rights to be extinguished by the project.

An example estimation of the number of development rights affected by an easement is in Appendix A, “Example Development Rights Calculation.”

Step 4: Determine the Urban or Rural designation for the Project Site using TIGERweb and American Fact Finder

This QM requires a determination of the land use setting, “Urban” or “Rural.” The urban-rural designation code is contained at the block level in Census data. The Census Bureau identifies two types of ‘Urban” areas:

- Urbanized Areas (UAs) of 50,000 or more people;
- Urban Clusters (UCs) of at least 2,500 and less than 50,000 people.

‘Rural’ areas encompass all population, housing, and territory not included within an urban area.

Spatial layers in census web-based applications can be reviewed visually and compared to a proposed project location using web-based tools maintained by the US Census Bureau to assist in this determination. Proposed projects may be entirely urban, entirely rural or a combination of both, which can be inferred visually at the block level. If a project spans more than one census block with differing urban-rural designations, applicants should split the project area into rural and urban components for the purposes of calculating avoided VMT.

Census Tools

Two census web-based applications may be used in conjunction with this QM to determine if a project area is assigned an urban or rural designation by the US Census Bureau: TIGERweb and American Fact Finder.

TIGERweb is a web-based mapping tool that allows users to visualize TIGER Census data. The application allows feature search by name, query by location, and geographic boundary display. There are two versions: TIGERweb and TIGERweb Decennial Applications (2010 Census). Both applications feature a layer to display census identified Urban Areas.

American Fact Finder provides data from a range of censuses and surveys. American Fact Finder also allows the selection and graphic display of all fully/partially urban census tracts or rural census tracts. Both TIGERweb and American Fact Finder provide graphic display of geographic entities and query functions.

Census Urban Areas Definitions

The census urban areas are composed of urbanized areas and urban clusters. The designation of the urban area boundaries are reviewed and updated every 10 years following the census. The most recent 2010 Census data contains the urban-rural designation at the block level, the smallest unit of area in the census. The census blocks are grouped into block groups, which in turn make up the census tracts. It is important to note that the urban/rural designation within the data attributes is available only at the block level. As a result, portions of a tract in a rural area may have different designations at the block level.

Census User Guides

The TIGERweb User Guide is available on the Census website, https://tigerweb.geo.census.gov/tigerwebmain/TIGERweb_User_Guide.pdf. The guide provides an overview of the step by step procedure for using TIGERweb to view census tract boundaries or obtain the census tract number. Census representatives recommend using Internet Explorer or Firefox, as functionality may not be available in other browsers unless popups from the U.S. Census website are allowed.

Guidance for using American Fact Finder is available online at http://factfinder.census.gov/faces/nav/jsf/pages/using_factfinder.xhtml. Using advanced search, all available data by topic and geographic area is searchable. American Fact Finder was chosen for the example in this document due to its ease of use in locating the project area and displaying census blocks to determine the proper designation.

Digital GIS Data files Available from the Census

Census data are available as GIS shapefiles by state or through the web data services for GIS software users. The census layer featuring the urban areas displays the spatial extent of the urban-rural designation. See the "TIGERLine How to guides" on the U.S. Census website for acquiring digital files for use with ArcGIS at: https://www.census.gov/geo/education/howtos.html, or the guide to TIGER shapefiles at: http://www2.census.gov/geo/pdfs/education/tiger/Downloading_TIGERLine_Shp.pdf.

ArcGIS users may access the TIGERweb data layers using census data or through ArcGIS REST Services. This is a simple way to access the most current data without storing and managing data locally. Census TIGERweb services are available at https://tigerweb.geo.census.gov.

See TIGERweb links for Urban or Tracts_Blocks at https://tigerweb.geo.census.gov/tigerwebmain/TIGERweb_restmapservice.html or the Census2010 map server link Urban or Tracts_Blocks at https://tigerweb.geo.census.gov/arcgis/rest/services/Census2010.

The Census FAQs document on urban and rural definitions, the Urban-Rural Classification Program, and urban-rural delineation results are a useful reference. Relationship files are available to search for places, counties, and urban areas. The tables can be searched to determine if a particular area of interest is within an urban area. Reference maps of each urban area are also available to help understand the spatial data.

Step 5: Determine the Soil Type of the Project Site Using SoilWeb

SoilWeb is used to determine the USDA soil order of the project site. This QM uses the Intergovernmental Panel on Climate Change (IPCC) Soil Classification to determine the carbon reference stock in the project site. Table 4 shows which USDA soil orders belong to each IPCC soil type.

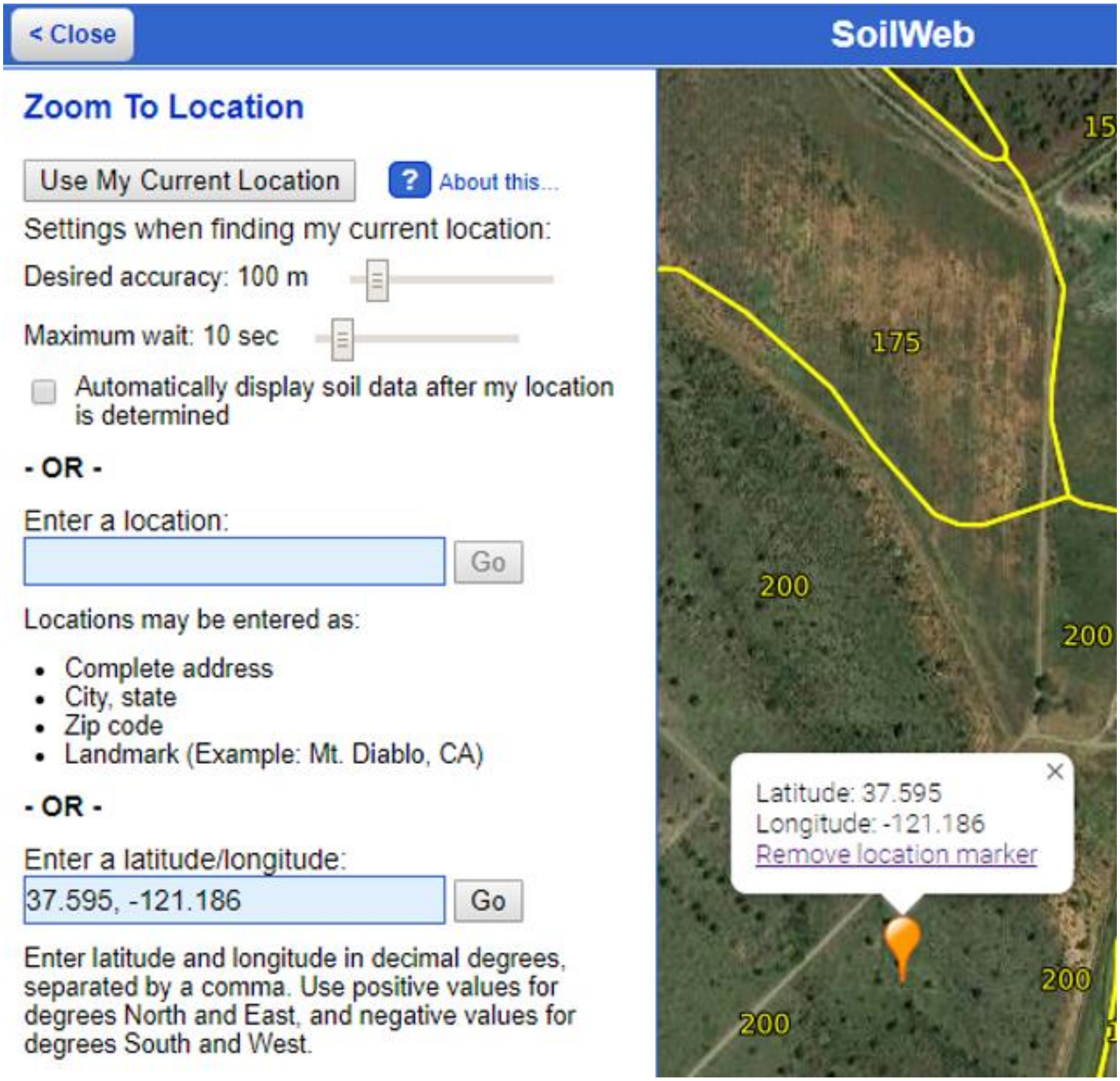
Table 4. USDA Soil Orders in each IPCC Soil Type

IPCC Soil Types	USDA Soil Orders
Organic Soils	Histosols
Sandy Soils	Soils with greater than 70% sand and less than 8% clay
Volcanic Soils	Andisols
Spodic Soils	Spodosols
Low Activity Clay Soils	Entisols, Gelisols, Oxisols, Utisols
High Activity Clay Soils	Alfisols, Aridisols, Inceptisols, Mollisols, Vertisols

After navigating to the web-based tool, SoilWeb,[4] select "OK" to begin using SoilWeb. Select "Menu" from top right corner of the screen, then select "Zoom to Location." Enter the project site location either as an address or as a latitude/longitude.

[4] University of California, Davis, California Soil Resource Lab. SoilWeb. https://casoilresource.lawr.ucdavis.edu/gmap/

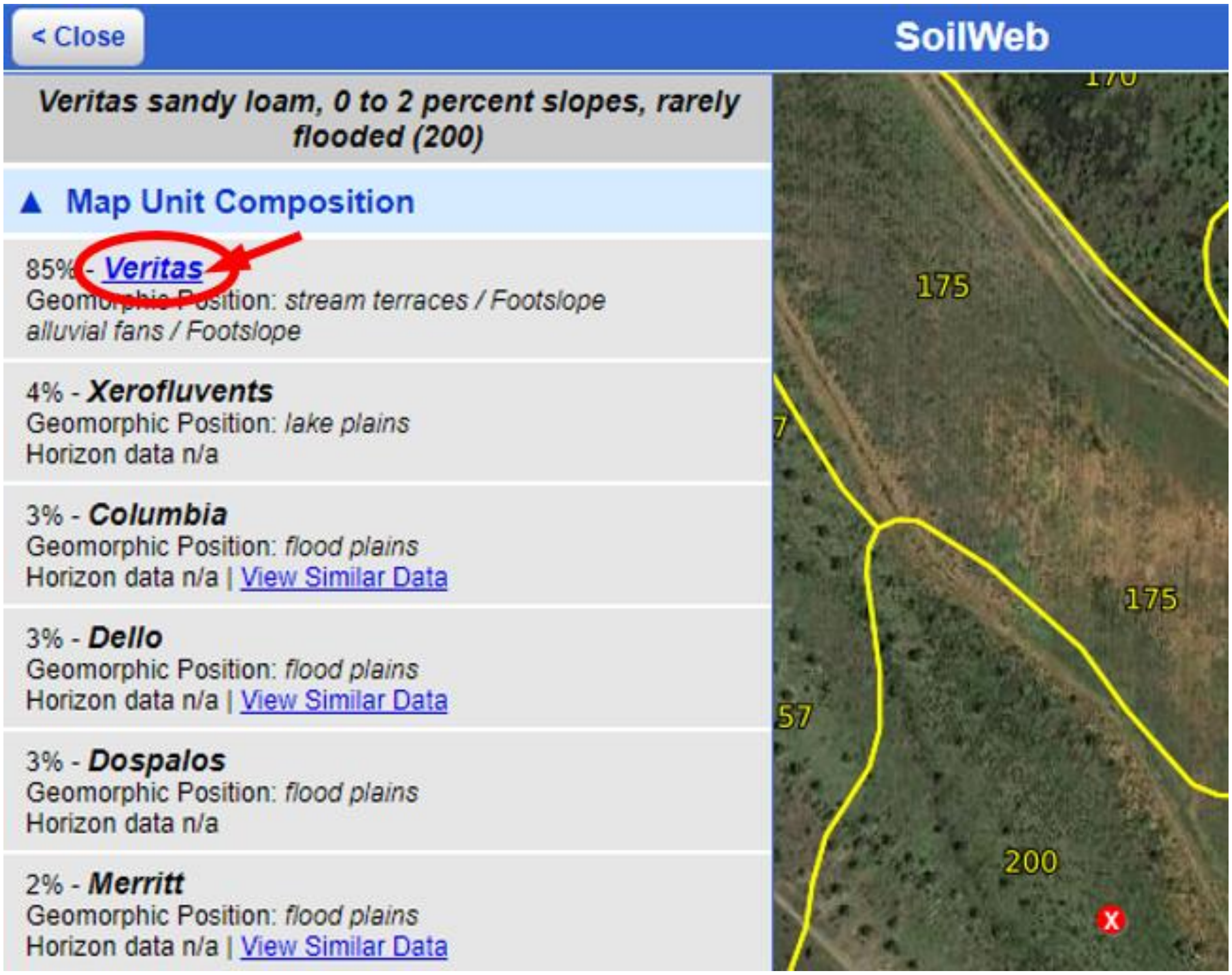
Figure 2. Finding Project Site Location on SoilWeb



After visually confirming that the map now includes the project site, note that the map is divided by many yellow lines into map units. Each map unit bounded by the yellow lines has a defined soil composition. Select one of the larger map units in the project site. A new box will appear in the upper right side of the screen with composition and data for that map unit.

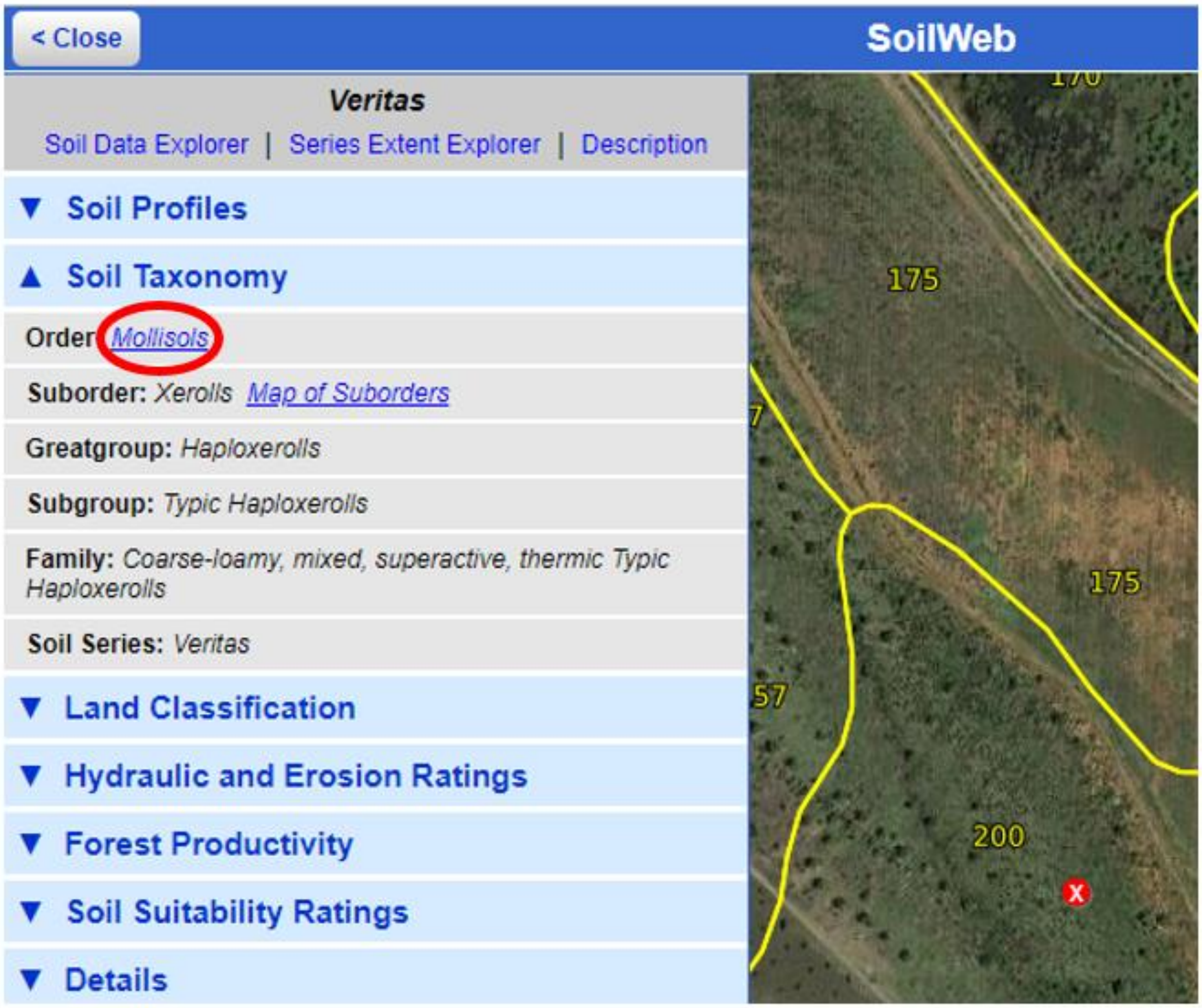
The “Map Unit Composition” section shows the different soil series identified in the selected map unit. The soil series with the largest component is in blue and underlined. Click on this soil series. (If the soil series is not blue and underlined, or if a water body or rock formation is the largest composition, click on adjacent map units within the project site until a blue and underlined soil series is available.)

Figure 3. SoilWeb Map Unit Composition



A new box shows characteristics for that soil series. Under the "Soil Taxonomy" section, note the soil order. This soil order will be input into the Agricultural Lands Conservation Benefit Calculator Tool.

Figure 4. Soil Order Input for Benefit Calculator Tool



Step 6: Estimate the Net GHG benefit and Selected Co-Benefits for the Proposed Project

Agency staff will use the Agricultural Lands Benefits Conservation Calculator Tool to complete this step. The Tool can be downloaded from: www.arb.ca.gov/cci-resources.

Each tab in the Tool is identified by a name and cells in the tab are coded by colors:

- Green fields indicate direct user input is required for benefit calcuation.
- Blue fields are informational and user input is not required for benefit calculation.
- Grey fields indicate output or calculation fields that are automatically populated based on user entries and the calculation methods.
- Yellow fields offer helpful hints or important tips to the user.
- Black fields are not applicable and no user input is necessary.

Users should begin in the Tool with the **Read Me** tab, which contains general information about the Tool.

The **Project Info** tab in the Tool provides information about how to complete the tool.

The **Inputs** tab in the Tool is where all project characteristics are entered.

The **Summary** tab in the Tool displays the estimates for:

- Total Agricultural Lands Conservation GHG benefit ($MTCO_2e$);[5]
- Total GHG benefit ($MTCO_2e$);
- Total GHG benefit per total Agricultural Lands Conservation GGRF funds ($MTCO_2e/\$$); and
- Total GHG benefit per total funds ($MTCO_2e/\$$).
- Reactive Organic Gases (ROG) Emission Reduced (lbs)
- Nitrous Oxide (NO_x) Emission Reduced (lbs)
- PM2.5 Emission Reduced (lbs)
- Diesel PM Emission Reduced (lbs)
- Lands Conserved (acres)
- Soil Benefit (acres)
- Passenger VMT Reductions (miles)
- Travel Cost Savings (dollars)
- Transportation Fossil Fuel Use Reduction (gallons)

[5]This is the portion of GHG benefit attributable to funding from the Program; GHG emission reductions are prorated according to the level of program funding contributed from each California Climate Investments program funded with GGRF, as applicable. The results in the Co-benefits Summary tab are prorated using the same approach, as applicable.

A. Emission Reductions from Agricultural Lands Easement

Equation 1 estimates the GHG benefit (GHG_{ESMT}) from the proposed Agricultural lands Easement. Equation 1 relies on four other equations:

- Equation 2 estimates the GHG benefit (GHG_{VMT}) from reduced future VMT by urban households compared to rural households.
- Equation 5 estimates the GHG benefit (GHG_{ELEC}) from reduced future electricity use by urban households compared to rural households.
- Equation 6 estimates the GHG benefit (GHG_{NG}) from natural gas use by urban households compared to propane use by rural households.
- Equation 7 estimates the GHG benefit (GHG_{SOC}) from reduced future Vehicle Miles Traveled by urban households compared to rural households.

Equation 1: Total GHG Benefit from Agricultural Lands Easement

$$GHG_{ESMT} = GHG_{VMT} + GHG_{ELEC} + GHG_{NG} + GHG_{SOC}$$

Where,			Units
GHG_{ESMT}	=	GHG benefit from proposed agricultural land easement	$\mathrm{MT\ CO_2e}$
GHG_{VMT}	=	GHG benefit from reduced future VMT by urban households compared to rural households	$\mathrm{MT\ CO_2e}$
GHG_{ELEC}	=	GHG benefit from reduced future electricity use by urban households compared to rural households	$\mathrm{MT\ CO_2e}$
GHG_{NG}	=	GHG benefit from use of natural gas by urban households compared to use of propane by rural households	$\mathrm{MT\ CO_2e}$
GHG_{SOC}	=	GHG benefit from avoided loss of soil organic carbon due to land use change from farmland to settlements	$\mathrm{MT\ CO_2e}$

B. Emission Reductions from VMT Reduction

Equation 2 estimates the GHG benefit (GHG_{VMT}) from the reduction in future VMT by shifting housing development from the easement site to urban locations in the region. The VMT that would have occurred at the easement site, calculated in Equation 3, is dependent on whether the easement site has a rural or urban designation, as determined in Step 3. The VMT that will occur instead at urban locations in the region, calculated in Equation 4, has the same dependence. A description of VMT calculations for rural and urban regions is in Appendix A.

Equation 2: GHG Benefit from VMT Reduction due to Easement

$$GHG_{VMT} = 10^{-9} \times \sum_{Imp=Yr}^{Imp+30} AVEF_{Yr,County} \times (VMT_{BL} - VMT_{PR})$$

Where,			Units
GHG_{VMT}	=	GHG benefit from reduced future VMT by urban households compared to rural households	$\mathrm{MT\ CO_2e}$
10^{-9}	=	Conversion from grams to metric tons	$\frac{\mathrm{MT}}{\mathrm{g}}$
Imp	=	Year in which in the project is implemented	Year
Yr	=	Year of emissions evaluation	Year
30	=	Project Life of an agricultural lands easement	Years
$AVEF_{Yr,County}$	=	Auto Vehicle Emission Factor by year and by county; see Database. (For Years greater than 2050, $AVEF_{Yr,County} = AVEF_{2050,County}$)	$\frac{\mathrm{g\ CO_2e}}{\mathrm{mile}}$
VMT_{BL}	=	Estimated baseline future household VMT avoided at easement site (see Equation 3)	$\frac{\mathrm{miles}}{\mathrm{year}}$
VMT_{PR}	=	Estimated project future household VMT created away from easement site in a regional urban location (see Equation 4)	$\frac{\mathrm{miles}}{\mathrm{year}}$

Equation 3: Baseline VMT for Agricultural Lands

$$VMT_{BL} = \begin{cases} VMT_{Rural} \times HH, & \text{for Rural Sites} \\ VMT_{Urban} \times HH, & \text{for Urban Sites} \end{cases}$$

Where,

			Units
VMT_{BL}	=	Estimated baseline future annual VMT created at easement site if developed into housing	$\frac{\text{miles}}{\text{yr}}$
VMT_{Rural}	=	Estimated average rural household annual VMT for the project site region (see Appendix A)	$\frac{\text{miles}}{\text{DU}-\text{yr}}$
VMT_{Urban}	=	Estimated average urban household annual VMT for the project site's region (see Appendix A)	$\frac{\text{miles}}{\text{DU}-\text{yr}}$
HH	=	Number of household dwelling unit development rights extinguished at project site by the easement, as calculated in Step 3.	DU

Equation 4: Project VMT due to Agricultural Lands Easement

$$VMT_{PR} = \begin{cases} VMT_{Urban} \times HH, & \text{for Rural Sites} \\ VMT_{Urban} \times \left(1 - MIN\left(0.3, 0.07 \times \dfrac{\frac{HH}{A_{PR}} - 2.46}{2.46}\right)\right) \times HH, & \text{for } \dfrac{HH}{A_{PR}} > 2.46 \\ VMT_{Urban} \times HH & \text{for } \dfrac{HH}{A_{PR}} \leq 2.46 \end{cases}$$

			Units
VMT_{PR}	=	Estimated project future annual household VMT created by new housing development away from easement site in a regional urban location	$\frac{\text{miles}}{\text{yr}}$
VMT_{Urban}	=	Estimated average urban VMT for the project site region (see Appendix A)	$\frac{\text{miles}}{\text{DU}-\text{yr}}$
0.3	=	Maximum urban VMT reduction (LUT-1)	unitless
0.07	=	Elasticity of urban VMT with respect to density	unitless
HH	=	Number of household dwelling unit development rights extinguished at project site by the easement, as calculated in Step 3.	DU
A_{PR}	=	Area of project site evaluated for housing development	acres
2.46	=	State average urban household density	$\frac{\text{DU}}{\text{acre}}$

C. Emission Reductions from Electricity Reduction

Equation 5 estimates the GHG benefit (GHG_{ELEC}) from the reduction in future electricity use by households located in urban regions instead of at the easement site. A description of urban and rural electrical use is in Appendix B.

Equation 5: GHG Benefit from Reduced Future Electrical Use

$$GHG_{ELEC} = EF_{ELEC} \times (ELEC_{BL} - ELEC_{PR}) \times HH \times 30$$

Where,

			Units
GHG_{ELEC}	=	GHG benefit from reduced future electricity use by urban households compared to rural households	$\mathrm{MT\ CO_2e}$
EF_{ELEC}	=	Emission Factor for California Electrical Use (see Quantification Emission Factor Database)	$\frac{\mathrm{MT\ CO_2e}}{\mathrm{MWh}}$
$ELEC_{BL}$	=	Predicted Baseline Annual Household Electrical Use, equal to: • Annual new single family household rural electrical consumption for rural sites • Annual new single family household urban electrical consumption for urban sites (See Appendix B)	$\frac{\mathrm{MWh}}{\mathrm{DU-yr}}$
$ELEC_{PR}$	=	Predicted project annual household electrical use, equal to the annual new single family household urban electrical consumption (See Appendix B)	$\frac{\mathrm{MWh}}{\mathrm{DU-yr}}$
HH	=	Number of household dwelling unit development rights extinguished at project site by the easement, as calculated in Step 3	DU
30	=	Project life of an agricultural lands easement	Years

D. Emission Reductions from Natural Gas Use

Equation 6 estimates the GHG benefit (GHG_{NG}) from the use of natural gas instead of propane by households located in urban regions instead of at the easement site. A description of urban natural gas use and rural propane use is in Appendix B.

Equation 6: GHG Benefit from Natural Gas Use

$$GHG_{NG} = (EF_{BL} - EF_{PR}) \times NG_{Urban} \times HH \times 30$$

Where,

			Units
GHG_{NG}	=	GHG benefit from use of natural gas by urban households compared to use of propane by rural households	$\mathrm{MT\ CO_2e}$
EF_{BL}	=	Emission factor for the baseline scenario, equal to: • Propane emission factor for rural sites • Natural gas emission factor for urban sites (see Quantification Emission Factor Database)	$\frac{\mathrm{MT\ CO_2e}}{\mathrm{therm}}$
EF_{PR}	=	Emission factor for the project scenario, equal to the natural gas emission factor (see Quantification Emission Factor Database)	$\frac{\mathrm{MT\ CO_2e}}{\mathrm{therm}}$
NG_{Urban}	=	Predicted annual new single family urban household natural gas use	$\frac{\mathrm{therm}}{\mathrm{DU-yr}}$
HH	=	Number of household dwelling unit development rights extinguished at project site by the easement, as calculated in Step 3	DU
30	=	Project life of an agricultural lands easement	Years

E. Avoided Soil Organic Carbon Emissions

Equation 7 estimates the GHG benefit (GHG_{SOC}) from the avoided oxidation of soil organic carbon on mineral soils caused by land use change from farmland to housing. The easement keeps the soil organic carbon *in situ*. Soil organic carbon is lost from drained organic soils whether as farmland or as settlements. Housing developed in existing urban areas occurs on land that has already been converted from farmland; the soil organic carbon has already been lost.

Equation 7: Avoided Carbon Loss of Farmland due to Conversion to Housing

$$GHG_{SOC} = 30\% \times CS_{ref} \times \frac{44}{12} \div 2.47105 \times MIN\left(3, \frac{A_{PR}}{HH}\right) \times HH$$

Where,

			Units
GHG_{SOC}	=	GHG benefit from avoided loss of soil organic carbon due to land use change from farmland to settlements	$\text{MT CO}_2\text{e}$
30%	=	Land use factor to represent the loss of soil carbon with conversion to settlements	unitless
CS_{ref}	=	Reference carbon stock for project site IPCC soil type: • Sandy (16) • Wetland (48) • Volcanic (124) • Spodic (86) • High Activity Clay Soil (37) • Low Activity Clay Soil (25)	$\frac{\text{MT C}}{\text{Hectare}}$
$\frac{44}{12}$	=	Molecular weight ratio of carbon dioxide to carbon	$\frac{\text{MT CO}_2\text{e}}{\text{MT C}}$
2.47105	=	Conversion from hectares to acre	$\frac{\text{Acres}}{\text{Hectare}}$
3	=	Maximum number of acres per dwelling disturbed by development	$\frac{\text{Acres}}{\text{DU}}$
A_{PR}	=	Area of project site evaluated for housing development	acres
HH	=	Number of household dwelling unit development rights extinguished at project site by the easement, as calculated in Step 3.	DU

F. Emissions Co-Benefits

Equation 8 estimates the emissions benefit based on the reduction of future VMT and future electricity use. Emissions evaluated are particulate matter 2.5 microns or smaller (PM2.5), oxides of nitrogen (NO_x), reactive organic gases (ROG), and diesel particulate matter (diesel PM).

Equation 8: NO_x, ROG, $PM_{2.5}$ and Diesel PM Co-benefit from Project Implementation

$$CoBenefit = \sum_{Imp=Yr}^{Imp+30} AVEF_{Yr,County} \times (VMT_{BL} - VMT_{PR})$$
$$+EF_{ELEC} \times (ELEC_{BL} - ELEC_{PR}) \times HH \times 30$$
$$+(EF_{BL} - EF_{PR}) \times (NG_{Urban}) \times HH \times 30$$

Where,

			Units
$CoBenefit$	=	PM2.5, NO_x, ROG, and Diesel PM co-benefit from future reduction of VMT and electricity use due to easement project	lb emission
$AVEF_{Yr,County}$	=	Auto Vehicle Emission Factor by year and by county; see Database. (For Years greater than 2050, $AVEF_{Yr,County} = AVEF_{2050,County}$)	$\frac{\text{lb emission}}{\text{mile}}$
VMT_{BL}	=	Estimated baseline future household VMT avoided at easement site (see Equation 3)	$\frac{\text{miles}}{\text{yr}}$
VMT_{PR}	=	Estimated project future household VMT created away from easement site in a regional urban location (see Equation 4)	$\frac{\text{miles}}{\text{yr}}$
EF_{ELEC}	=	NOx, ROG, PM 2.5 and Diesel PM Emission Factors for California electrical use (see Quantification Emission Factor Database)	$\frac{\text{lb emission}}{\text{MWh}}$
$ELEC_{BL}$	=	Predicted baseline annual household electrical use, equal to: • Annual household rural electrical use for rural sites • Annual household urban electrical use for urban sites (See Appendix B)	$\frac{\text{MWh}}{\text{DU} - \text{yr}}$
$ELEC_{PR}$	=	Predicted project annual household electrical use, equal to the annual household urban electrical use (See Appendix B)	$\frac{\text{MWh}}{\text{DU} - \text{yr}}$
HH	=	Number of household dwelling unit development rights extinguished at project site by the easement, as calculated in Step 3.	DU
30	=	Project life of an agricultural lands easement	Years
EF_{BL}	=	NOx, ROG and $PM_{2.5}$ emission factors for the baseline scenario, equal to: • Propane emission factor for rural sites • Natural gas emission factor for urban sites (see Quantification Emission Factor Database)	$\frac{\text{lb emission}}{\text{therm}}$
EF_{PR}	=	NOx, ROG and $PM_{2.5}$ emission factors for the project scenario, equal to the natural gas emission factor (see Quantification Emission Factor Database)	$\frac{\text{lb emission}}{\text{therm}}$
NG_{Urban}	=	Predicted urban natural gas use (See Appendix B)	$\frac{\text{therm}}{\text{DU} - \text{yr}}$

References

California Air Pollution Control Officers Association. (2017) *User's Guide for CalEEMod version 2016.3.2.* http://www.caleemod.com/.

California Air Resources Board. (2015) *Compliance Offset Protocol, U.S. Forest Projects.* https://ww3.arb.ca.gov/cc/capandtrade/protocols/usforest/forestprotocol2015.pdf.

California Air Resources Board. (2017). *California Climate Investments Quantification Methodology Emission Factor Database*. www.arb.ca.gov/cci-quantification.

California Air Resources Board. (2018). *Funding Guidelines for Agencies Administering California Climate Investments.* https://ww3.arb.ca.gov/cc/capandtrade/auctionproceeds/2018-funding-guidelines.pdf.

California Air Resources Board. (2018) *EMFAC Web Database.* https://www.arb.ca.gov/emfac/.

California Department of Transportation. (2009) *California Metropolitan Planning Organizations (MPOs) and Regional Transportation Planning Agencies (RTPAs).* http://www.dot.ca.gov/hq/tpp/images/rtpa_mpo_map.pdf.

California Department of Transportation. (2016) *California Statewide Travel Demand Model.* http://www.dot.ca.gov/hq/tpp/offices/omsp/statewide_modeling/cstdm.html.

California Energy Commission. (2010) *2009 California Residential Appliance Saturation Study.* https://ww2.energy.ca.gov/appliances/rass/.

California Energy Commission. (2016) *California Energy Consumption Database.* http://ecdms.energy.ca.gov/.

California Strategic Growth Council. (2018) *California Sustainable Agricultural Lands Conservation Program Grant Guidelines & Applications.* http://sgc.ca.gov/programs/salc/docs/20190123-FINAL_18-19_SALCP_Guidelines.pdf

California Wildlife Conservation Board. (2018) *Climate Adaptation and Resiliency Program Guidelines.* https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=156228.

City of Brea. (2004) *Brea Hillside Zoning Ordinance*. http://www.cityofbrea.net/DocumentCenter/View/60/Brea-Hillside-Zoning-Ordinance.

City of Cupertino. *General Plan Appendix F: Slope Density.* https://www.cupertino.org/home/showdocument?id=12738.

City of Fremont. (2011) *General Plan, Chapter 2 – Land Use.* https://fremont.gov/DocumentCenter/View/4665/02-Land-Use.

City of Gilroy. (2019) *Gilroy City Code, Article IX. RH Residential Hillside District.* https://www.codepublishing.com/CA/Gilroy/html/Gilroy30/Gilroy3009.html.

City of Glendale. *Glendale Municipal Code, Chapter 30.11 – Residential Districts.* https://www.glendaleca.gov/Home/ShowDocument?id=4915.

City of Palm Springs. *Palm Springs Municipal Code, Chapter 92 – Zoning Regulations.* http://www.qcode.us/codes/palmsprings/view.php?topic=zoning_code-92_00-92_01_00.

City of Laguna Beach. *Laguna Beach Municipal Code, Chapter 25.15 – R/HP Residential/Hillside Protection Zone.* https://qcode.us/codes/lagunabeach/view.php?topic=25-25_15-25_15_010.

City of Oakland. *Chapter 17.13 – RH Hillside Residential Zones Regulations.* http://www2.oaklandnet.com/oakca/groups/ceda/documents/report/oak027095.pdf.

City of Pasadena. *Code of Ordinances, Chapter 17.29 – Hillside Overlay Districts.* https://library.municode.com/ca/pasadena/codes/code_of_ordinances?nodeId=TIT17_ZONING_CODE_ART2ZODIALLAUSZOECST_CH17.29HIOVDI

City of San Rafael. *Hillside Development Guidelines.* https://storage.googleapis.com/proudcity/sanrafaelca/uploads/Hillside-Guidelines-Handout.pdf.

City of San Ramon. (2018) *City of San Ramon Zoning Ordinance, Division D2 – Allowable Land Uses and Zoning Standards*. http://www.sanramon.ca.gov/UserFiles/Servers/Server_10826046/File/Our%20City/Departments/Community%20Development/Planning/Zoning%20Ordinance/Division%20D-2%20Effective%202018-03-28.pdf

City of Santa Paula. *Zoning Code, Chapter 16.07 – Establishment of Zones.* http://www.ci.santa-paula.ca.us/planning/zoningcode/ZoningDistricts-LandUseRegulations.pdf

City of Santa Rosa. *Santa Rosa City Code, Chapter 20-32 - Hillside Development Standards.* http://qcode.us/codes/santarosa/view.php?topic=20-3-20_32

City of Saratoga. *Hillside Residential (HR) Zoning District*. https://www.saratoga.ca.us/DocumentCenter/View/54/Hillside-Residential-HR-PDF.

City of Temecula. *Temecula Municipal Code, Chapter 17.06 – Residential Districts.* https://qcode.us/codes/temecula/view.php?topic=17-17_06-17_06_020.

Colorado State University, Natural Resource Ecology Laboratory. *IPCC Soil Classification Based on USDA Taxonomy.* https://www2.nrel.colostate.edu/projects/ALUsoftware/files/presentations/IPCC_Climate_Soil_Classifications.pps.

County of Santa Clara. (2018) *Zoning Ordinance, Article 2 – Base Districts*. https://www.sccgov.org/sites/dpd/DocsForms/Documents/ZonOrd.pdf.

Institute of Transportation Engineers. (2017) *Trip Generation Manual, 10th Edition.* Washington D.C. https://www.ite.org/technical-resources/topics/trip-and-parking-generation/trip-generation-10th-edition-formats/.

Intergovernmental Panel on Climate Change. (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use.* IGES, Japan: Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html.

Town of Los Gatos. (2015) *HR Zoning District Summary Handout.* https://www.losgatosca.gov/DocumentCenter/View/354/HR-Zone-Handout.

Town of San Anselmo. *Code of Ordinances, Article 4. – Development Standards.* https://library.municode.com/ca/san_anselmo/codes/code_of_ordinances?nodeId=TIT10PLZO_CH3ZO_ART4DEST_10-3.410TAHHIDEDIPA.

Town of Yucca Valley. *Town of Yucca Valley Development Code, Article 2: Zoning Districts and Development Standards.* http://www.yucca-valley.org/pdf/planning/2014_development_Code/Article_2_Ord_253_Zoning.pdf.

U.S. Census Bureau. (2012) *Population and Housing Unit Counts, CPH-2-6, California.* U.S. Government Printing Office, Washington DC. https://www.census.gov/prod/cen2010/cph-2-6.pdf

U.S. Department of Agriculture. (2014). *Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry: Methods for Entity-Scale Inventory.* Washington, D.C.: Eve, M., Pape, D., Flugge, M., Steele, R., Man, D., Riley-Gilbert and M., Biggar, S. (eds). https://www.usda.gov/oce/climate_change/estimation.htm.

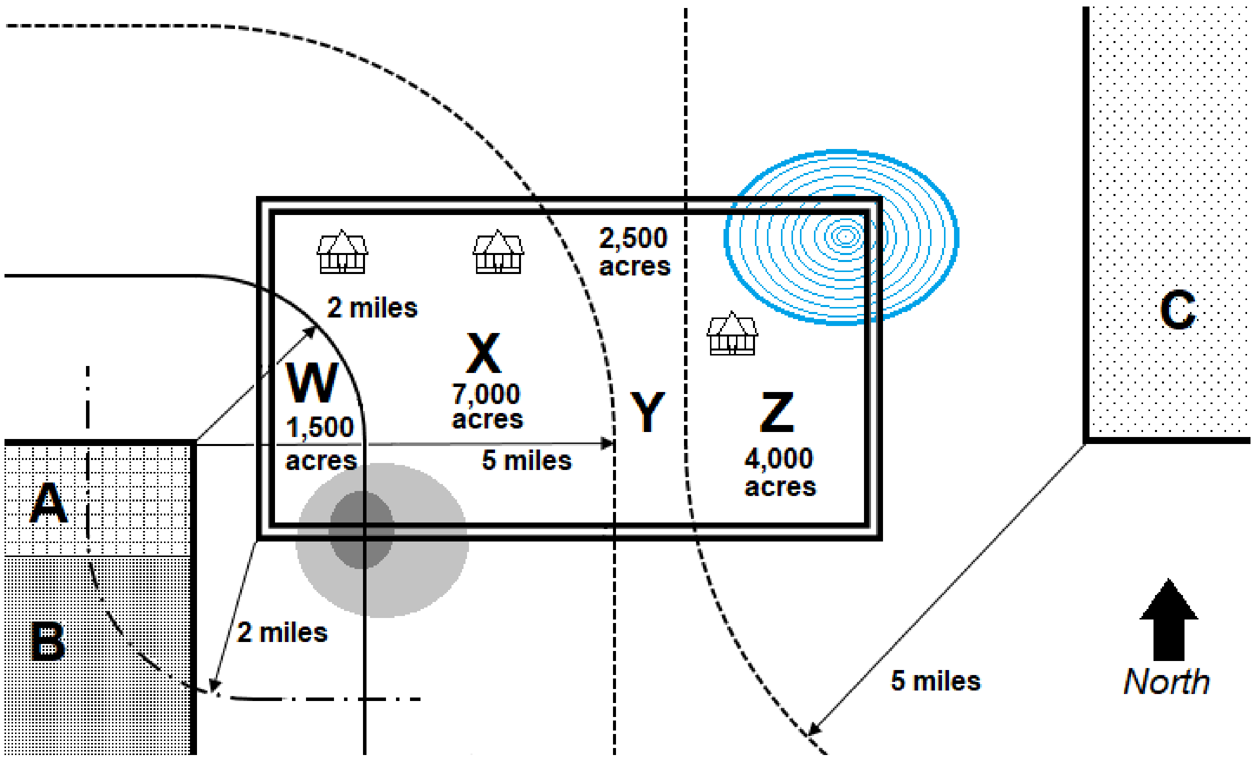
U.S. Department of Agriculture. (2016). *U.S. Agriculture and Forestry Greenhouse Gas Inventory 1990-2013.* Technical Bulletin No. 1943. https://www.usda.gov/oce/climate_change/AFGG_Inventory/USDA_GHG_Inventory_1990-2013_9_19_16_reduced.pdf

U.S. Environmental Protection Agency. (2019) *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017.* https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2017.

Appendix A. Example Development Rights Calculation

This appendix demonstrates the development rights calculation method, as outlined in Step 3 of this QM, for a fictitious agricultural easement. The easement is shown below as the double-lined rectangle in the center of Figure 5. The easement has an area of 15,000 acres. The easement is currently zoned for agriculture at 40 acres per dwelling unit, or 0.025 DU/acre. There is a hill to the southwest of the easement and a section of a lake in the northeast of the easement.

Figure 5. Fictitious Agricultural Easement Example. (Not to scale)



There is an urban area to the southwest of the agricultural easement. Area A is a residential area with an average density of 3 DU/acre. The median year that single family homes were constructed in A is 1996. Area B is is a residential area with an average density of 6 DU/acre. The median year that single family homes were constructed in B is 1979. There is an urban cluster to the east of the easement. Cluster C is a rural residential area with an average density 0.25 DU/acre (4 acres/DU).

There is a section of the easement, W, that is within 2 miles of A and B, defined by the solid line. Section W has an area of 1,500 acres. A portion of W includes a hill, of which 180 acres has grades between 20% and 25%, and 120 acres has grades greater than 30%. The remaining 1,200 acres in W have grades less than 15%.

There is a section of the easement, X, that is within 2 and 5 miles of A and B, defined by the solid and dashed lines. Section X has an area of 7,000 acres. A portion of X includes a hill, of which 320 acres has grades between 20% and 25%, and 80 acres has grades greater than 30%. There are 6,920 acres in X with grades less than 30%. There are two existing dwelling units in section X.

There is a section of the easement, Y, that is greater than 5 miles from A, B or C, defined by the two dashed lines. Section Y has an area of 2,500 acres and demonstrates risk of conversion to current zoning minimums. All 2,500 acres in Y have grades less than 15%.

There is a section of the easement, Z, that is within 5 miles of C, defined by the dashed line. Section Z has an area of 4,000 acres. A portion of Z is a lake. The area of the lake in Z is 800 acres. The remaining 3,200 acres in Z have grades less than 15%. There is one existing dwelling unit in section Z.

Estimated extinguished housing developments in section W

Section W is at risk of development to residential zoning because it is less than two miles from existing residential zoning.

The residential zoning housing density to be assigned to the area in W with grades less than 15% is the smallest of the residential densities within 2 miles of W, as defined by the dash-dot line. Areas A and B are within 2 miles of W. The single family homes in Area A were constructed more recently than the single family homes in Area B. The housing density of A will be used to estimate the housing density in section W. A housing density of 3 DU/acre is applied to the 1,200 acres in W where the grades are less than 15%.

A reduced housing density is assigned to the area in W with grades between 20% and 25%. For grades between 20% and 25%, the reduction is 20%. A housing density of 2.4 DU/acre is applied to the 180 acres where the grades are between 20% and 25%.

A reduced housing density is assigned to the area in W with grades greater than 30%. For grades greater than 30%, the housing density for residential areas is 0.5 DU/acre. A housing density of 0.5 DU/acre is applied to the 120 acres where the grades are greater than 30%.

The number of extinguished housing development rights in W is the sum of the products of the different areas in W by their respective densities:

$$3\ \text{DU/acres} \times 1{,}200\ \text{acres} + 2.4\ \text{DU/acre} \times 180\ \text{acres} + 0.5\ \text{DU/acre} \times 120\ \text{acres} = 4{,}092\ \text{DU}$$

There are 4,092 housing development rights extinguished in section W.

Estimated extinguished housing developments in section X

Section X is at risk of development to rural residential zoning because it is more than two miles but less than five miles from existing residential zoning.

The rural residential zoning housing density to be assigned to the area in X with grades less than 30% is 0.333 DU/acre because there is no rural residential zoning within five miles of X, only residential zoning. A housing density of 1/3 DU/acre is applied to the 6,920 acres in W where the grades are less than 30%.

A reduced housing density is assigned to the area in X with grades greater than 30%. For grades greater than 30%, the housing density for rural residential areas is 0.1 DU/acre. A housing density of 0.1 DU/acre is applied to the 80 acres where the grades are greater than 30%.

The number of extinguished housing developpment rights in X is the sum of the products of the different areas in W by their respective densities, less the two existing dwelling units in section X:

$$1 \text{ DU}/ 3 \text{ acres} \times 6{,}920 \text{ acres} + 0.1 \text{ DU/acre} \times 80 \text{ acres} - 2 \text{ DU} = 2{,}312.67 \text{ DU}$$

There are 2,312 housing development rights extinguished in section X.

Estimated extinguished housing developments in section Y

Section Y is at risk of development to current zoning minimums because it has one of the risk options for conversion to current lot minimums.

The current allowed housing density of 0.025 DU/acre is applied to the 2,500 acres in Y.

The number of extinguished housing development rights in Y is the sum of the products of the different areas in Y by their respective densities:

$$0.025 \text{ DU/acre} \times 2{,}500 \text{ acres} = 62.5 \text{ DU}$$

There are 62 housing development rights extinguished in section Y.

Estimated extinguished housing developments in section Z

Section Z is at risk of development to rural residential zoning because it is less than five miles from existing rural residential zoning. The 800 acres of lake in Z cannot be converted to housing and are considered not at risk.

The rural residential zoning housing density to be assigned to the area in Z with grades less than 30% is equal to the average density of the rural residential housing in C, 0.25

DU/acre. A housing density of 0.25 DU/acre is applied to the 3,200 acres of developable land in W where the grades are less than 30%.

The number of extinguished housing development rights in Z is the sum of the products of the different areas in W by their respective densities, less the existing dwelling unit in section Z:

$$0.25 \text{ DU/acre} \times 3{,}200 \text{ acres} - 1 \text{ DU} = 799 \text{ DU}$$

There are 799 housing development rights extinguished in section Z.

Estimated extinguished housing developments in the easement

The total number of extinguished housing development rights in the easement is the sum of the different extinguished housing development rights from each of the sections:

$$4{,}092 \text{ DU} + 2{,}312 \text{ DU} + 62 \text{ DU} + 799 \text{ DU} = 7{,}265 \text{ DU}$$

A total of 7,265 dwelling unit development rights will be extinguished with this easement.

Appendix B. VMT Estimates for Rural and Urban Regions

Vehicle Miles Traveled (VMT) per household estimates are provided by metropolitan planning organizations (MPOs). Where MPOs have not provided data, VMT estimates are averaged from information in the California Statewide Travel Demand Model (CSTDM), a tool developed by the California Department of Transportation (CalTrans), using a methodology described in the California Emissions Estimator Model (CalEEMod). The CSTDM is primarily intended to provide a baseline for statewide aggregated data rather than detailed regional forecasts. The Statewide Travel Model operates similarly to a standard regional travel demand model using the same variables but on a statewide basis. The CalEEMod methodology takes trip length, trip type, and trip generation to calculate annual VMT.

The CSTDM divides California into 5,454 Traffic Analysis Zones (TAZs). Of these, 5,412 TAZs have VMT estimates per household. The number of TAZs varies by county, with Alpine County and Sierra County each having one TAZ with VMT data, while Los Angeles County has 1,316 TAZs with VMT data. Each TAZ has trip length data for Home-to-Work, Home-to-Shopping, and Home-to-Other. CalEEMod uses this information with average State trip type and the trip generation rate from the Institute of Transportation Engineers *Trip Generation Manual, 10th Edition* to calculate the VMT.

While each TAZ provides trip lengths for households within each TAZ, those numbers cannot be directly used for this QM. The approach this QM takes is to compare two cases: first, what the VMT would be for houses built on a specific agricultural land, and second, the VMT of the same number houses built in a nearby urban area. While the location of the agricultural lands in the first case is known, the land use change of the TAZ to settlements makes the current specific trip length estimates for the location inaccurate. Conversely, the houses built in urban areas in the second case would not change the land use of TAZ, but the specific location of the urban area cannot be identified.

Averages of the trip lengths in multi-county regions are used to predict VMT using the CalEEMod methodology. An average value of rural VMT per household will not be as affected by land use change of a single project site, and an average value of urban VMT per household will accommodate the uncertainty of where housing would be built due to the easement. The following multi-county Metropolitan Planning Organizations (MPOs) provided VMT data and are each assigned a region: Butte County Association of Governments (BCAG), Sacramento Area Council of Governments (SACOG), Metropolitan Transportation Commission (MTC), Association of Monterey Bay Governments (AMBAG), San Luis Obispo Council of Governments (SLOCOG) and Southern California Association of Governments (SCAG). Other counties are assigned regions based on geographical characteristics: the North Coast, Western Range, Sacramento Valley, Mountain counties, and San Joaquin Valley. Santa Barbara County and San Diego County are evaluated individually. El Dorado County and Placer County are divided into the SACOG and Mountain regions. A map of the regions is shown below in Figure 6.

Figure 6. California Regions for CSTDM TAZ VMT Analysis

While TAZs provide VMT per household estimates, CalTrans has not designated TAZs as rural or urban. Census blocks in California are designated rural and urban, but the boundaries of census blocks and TAZs do not align. Consequently, TAZs were characterized as urban if they contained at least 3.64 percent area of urban census blocks, and rural if they did not. The 3.64 percent area threshold was established because the resulting distribution of rural and urban populations matched the rural and urban population distribution from the 2010 census. The number of rural and urban TAZs for each multi-county region is shown below in Table 5.

Table 5. Urban and Rural Traffic Analysis Zones by Region

Region	Rural TAZ Count	Urban TAZ Count
North Coast	33	19
Western Range	25	4
Sacramento Valley	19	26
BCAG	9	20
Mountain	30	13
SACOG	37	293
MTC	27	1,104
San Joaquin Valley	140	549
AMBAG	15	94
SLOCOG	8	26
Santa Barbara County	8	50
SCAG	81	2,302
San Diego County	12	468

The VMT per household for the rural and urban areas of each region are estimated as the arithmetic average of the VMT per household of the rural and urban TAZs in that region. The VMT per household estimates used in the Tool, from MPO and CSTDM sources, by region and county, by rural and urban area, are shown below in Table 6.

Table 6. Annual Vehicle Miles Traveled by Rural and Urban Households

County	Region	Urban VMT mi/du-yr	Rural VMT mi/du-yr	MPO or CSTDM Source
Alameda	Metropolitan Transit Commission (MTC)	22,012	26,818	MPO
Alpine	Western Range	9,878	47,127	CSTDM
Amador	Mountain	21,970	46,473	CSTDM
Butte	Butte County Association of Governments (BCAG)	20,211	26,308	CSTDM
Calaveras	Mountain	21,970	46,473	CSTDM

County	Region	Urban VMT mi/du-yr	Rural VMT mi/du-yr	MPO or CSTDM Source
Colusa	Sacramento Valley	17,732	51,334	CSTDM
Contra Costa	MTC	24,914	29,696	MPO
Del Norte	North Coast	14,242	40,903	CSTDM
El Dorado (SACOG)	Sacramento Area Council of Governments (SACOG)	37,766	55,894	MPO
El Dorado (Tahoe Basin)	Mountain	21,970	46,473	CSTDM
Fresno	San Joaquin Valley	21,785	49,614	CSTDM
Glenn	Sacramento Valley	17,732	51,334	CSTDM
Humboldt	North Coast	14,242	40,903	CSTDM
Imperial	Southern California Association of Governments (SCAG)	14,620	24,141	MPO
Inyo	Western Range	9,878	47,127	CSTDM
Kern	San Joaquin Valley	21,785	49,614	CSTDM
Kings	San Joaquin Valley	21,785	49,614	CSTDM
Lake	North Coast	14,242	40,903	CSTDM
Lassen	Western Range	9,878	47,127	CSTDM
Los Angeles	SCAG	30,098	39,268	MPO
Madera	San Joaquin Valley	21,785	49,614	CSTDM
Marin	MTC	23,631	29,432	MPO
Mariposa	Mountain	21,970	46,473	CSTDM
Mendocino	North Coast	14,242	40,903	CSTDM
Merced	San Joaquin Valley	21,785	49,614	CSTDM
Modoc	Western Range	9,878	47,127	CSTDM
Mono	Western Range	9,878	47,127	CSTDM
Monterey	Association of Monterey Bay Area Governments (AMBAG)	41,852	45,259	MPO
Napa	MTC	23,510	27,824	MPO
Nevada	Mountain	21,970	46,473	CSTDM
Orange	SCAG	28,140	34,616	MPO
Placer (SACOG)	SACOG	28,702	54,743	MPO

County	Region	Urban VMT mi/du-yr	Rural VMT mi/du-yr	MPO or CSTDM Source
Placer (Tahoe Basin)	Mountain	21,970	46,473	CSTDM
Plumas	Mountain	21,970	46,473	CSTDM
Riverside	SCAG	34,136	38,253	MPO
Sacramento	SACOG	23,251	45,552	MPO
San Benito	AMBAG	47,277	57,792	MPO
San Bernardino	SCAG	32,418	39,057	MPO
San Diego	San Diego County	24,312	65,845	CSTDM
San Francisco	MTC	16,183	N/A	MPO
San Joaquin	San Joaquin Valley	21,785	49,614	CSTDM
San Luis Obispo	San Luis Obispo Council of Governments (SLOCOG)	14,240	36,652	MPO
San Mateo	MTC	21,067	32,904	MPO
Santa Barbara	Santa Barbara County	13,236	37,882	CSTDM
Santa Clara	MTC	19,656	26,921	MPO
Santa Cruz	AMBAG	31,294	39,179	MPO
Shasta	Sacramento Valley	17,732	51,334	CSTDM
Sierra	Mountain	21,970	46,473	CSTDM
Siskiyou	Western Range	9,878	47,127	CSTDM
Solano	MTC	25,380	28,327	MPO
Sonoma	MTC	20,736	26,505	MPO
Stanislaus	San Joaquin Valley	21,785	49,614	CSTDM
Sutter	SACOG	20,915	49,386	MPO
Tehama	Sacramento Valley	17,732	51,334	CSTDM
Trinity	North Coast	14,242	40,903	CSTDM
Tulare	San Joaquin Valley	21,785	49,614	CSTDM
Tuolumne	Mountain	21,970	46,473	CSTDM
Ventura	SCAG	28,451	35,036	MPO
Yolo	SACOG	25,088	54,616	MPO
Yuba	SACOG	33,128	66,363	MPO

Appendix C. Rural and Urban Household Utility Consumption

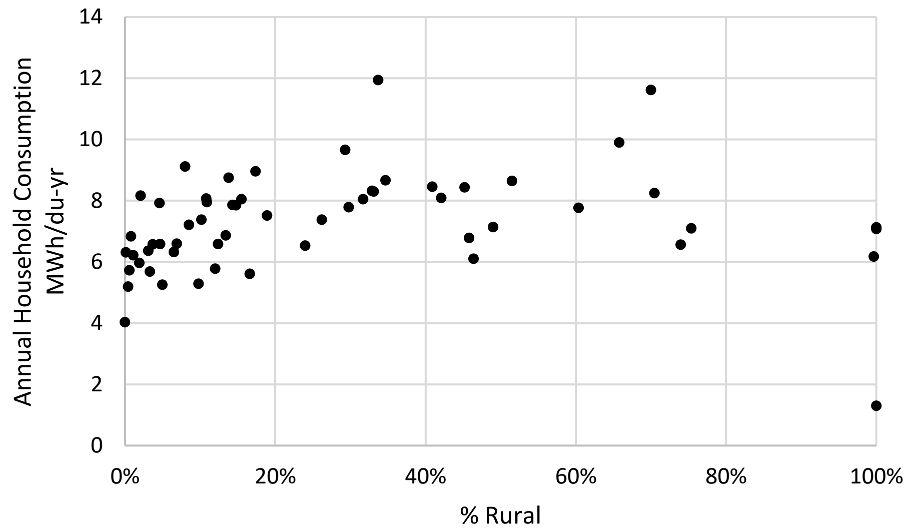
Rural and urban electricity and natural gas consumption for new single family households must be estimated for the QM to determine the GHG benefit and co-benefits associated with development of housing in urban areas instead of rural ones.

Existing models, such as the Cool California Carbon Calculator, estimate electricity and natural gas use by zip code, number of residents in a household, and household habits. Much of this information is unavailable for the QM, which only calculates the number of households and not additional household characteristics. Like the VMT analysis, the land use change at the project site and the uncertainty of urban locations make current estimates regarding electricity and natural gas use inaccurate.

The average household rural and urban electricity and natural gas use are calculated as statewide averages using the household electricity and natural gas use and percent rural population by county. Electricity and natural gas use by county are available in the California Energy Commission's (CEC) California Energy Consumption Database (CEC Database). The number of households and rural population of each county is found in the 2010 U.S. Census. CEC Database values from 2010 will be used for consistency with Census and CSTDM values. These values are then adjusted to match the change in electricity and natural gas use from average households and newly constructed households, and average households and single family household. The adjusted numbers are used in the Tool to determine the GHG benefit and co-benefits associated with development of housing in urban areas instead of rural ones.

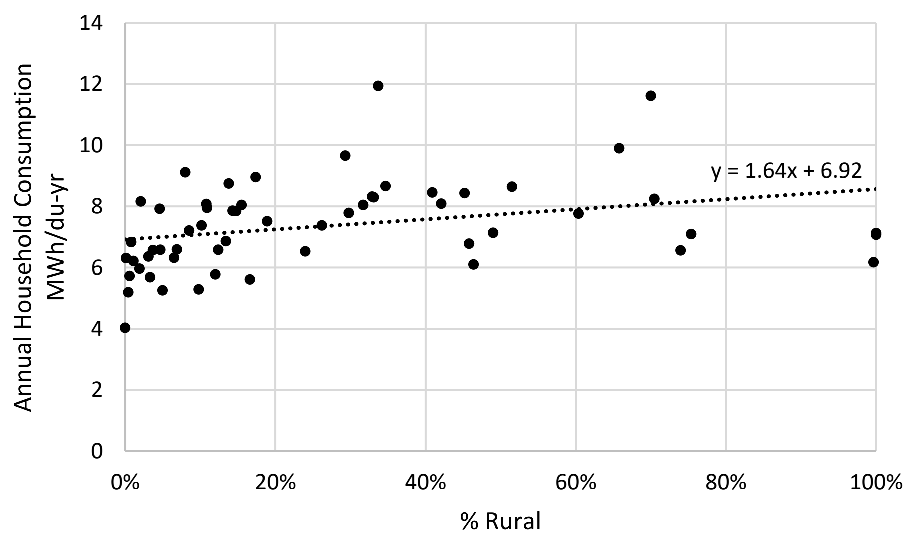
Average household electrical consumption by county is shown below in Figure B-1. The household electrical consumption for Trinity County is identified as an outlier using Tukey's Fences method and is removed from the distribution before rural and urban averages are predicted.

Figure 6. Average Household Electrical Consumption by County



A linear regression of the remaining counties is shown below in Figure B-2.

Figure 7. Linear Regression of Average Household Electrical Consumption by County



The linear regression equation calculated from the data predicts that, in California, the household electrical consumption is a function of the rural percentage of the household's county as:

Equation 9: Predicted Household Electricity Consumption by Rural Percentage

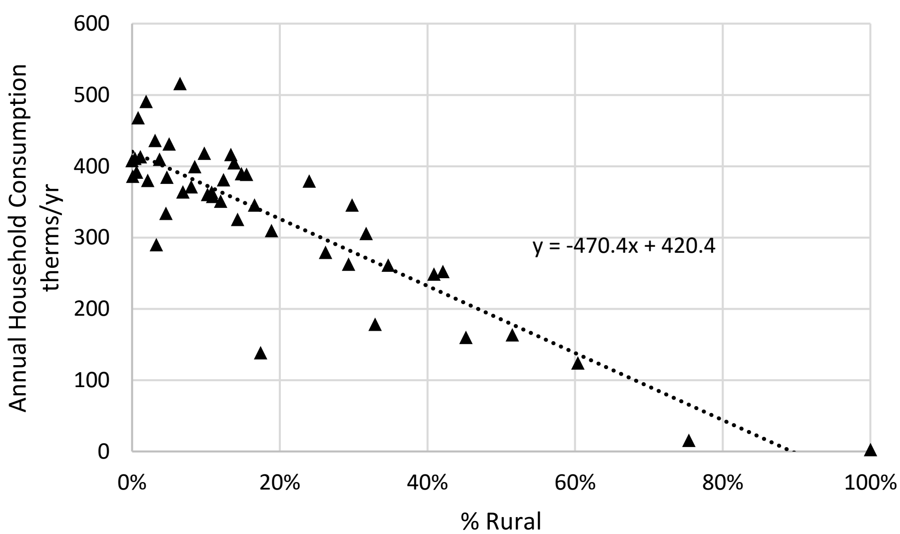
$$Household\ Electricity\ Consumption\ \left(\frac{MWh}{yr}\right) = 1.64 \times (Rural\,\%) + 6.92$$

Using this equation, the statewide predicted urban annual household electricity consumption is 6.92 MWh/du-yr, and the predicted rural annual household electricity consumption is 8.52 MWh/du-yr. These values must now be adjusted to estimate new single family urban and rural consumption.

The CEC Residential Appliance Saturation Study (RASS) is a comprehensive study of residential sector energy use in California. The RASS shows that single family homes consume 20.8% more electricity than the average household, which includes single family homes, townhomes, small and large apartments, and mobile homes. The RASS shows that households built after 2003 consume 5.5% more electricity than homes built before 2003. Using these adjustments, these statewide predicted electricity consumption for new single family urban and rural households are respectively 8.82 and 10.86 MWh/du-yr.

A similar procedure is used to calculate urban natural gas consumption by comparing the county annual household natural gas consumption and the rural percent of the population of each county. The relationship is shown below with linear regression in Figure 8.

Figure 8. Average Household Natural Gas Consumption by County



Average household natural gas consumption decreases as the rural population percentage of a county increases as described in Equation 10:

Equation 10: Predicted Household Natural Gas Consumption by Rural Percentage

$$Household\ Natural\ Gas\ Consumption\ \left(\frac{therm}{yr}\right) = -470.4 \times (Rural\ \%) + 420.4$$

This decreasing use of natural gas in more rural counties occurs because rural households are typically not connected to the natural gas distribution system. Rural households instead rely on other sources, such as liquid petroleum gas (LPG), wood, and electricity to meet the heating and cooking needs that natural gas would have provided. Data on rural household consumption of these natural gas substitutes are not readily available. Instead, this methodology assumes that the same household heating demand provided by natural gas to urban areas will be provided to rural households by propane as LPG. The GHG benefit from using natural gas instead of propane is the most conservative benefit that can be made by fuel choice.

The predicted urban natural gas annual consumption is 420.4 therm/du-yr and the assumed rural propane annual consumption is 420.4 therm/du-yr. These values must now be adjusted to estimate new single family urban and rural consumption. The RASS shows that single family homes consume 18.9% more natural gas than the average household, which includes single family homes, townhomes, small and large apartments, and mobile homes. The RASS shows that households built after 2003 consume 1.9% more natural gas than homes built before 2003. Using these adjustments, the statewide predicted natural gas consumption for new single family urban households and propane consumption for new single family rural households is 505.6 therm/du-yr.